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# Selection for Intramuscular Fat in Duroc Swine – An Update

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**Abstract**

Long-term progress or improvement in many economically important traits is ultimately the responsibility of the seedstock supplier. If selection progress is to be made in traits of economic importance, the trait must: 1) be accurately measurable, 2) show sufficient heritability, and 3) display an adequate level of variation. For such reasons, tremendous progress has been made in the swine industry toward increasing lean meat percentage over the past quarter century. However, in more recent years, meat quality traits have received more attention and have become more important in breeding programs as producers and processors try to meet consumer demands for high quality, nutritious products.

**Disciplines**

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**Comments**

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## Selection for Intramuscular Fat in Duroc Swine – An Update

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### Introduction

Long-term progress or improvement in many economically important traits is ultimately the responsibility of the seedstock supplier. If selection progress is to be made in traits of economic importance, the trait must: 1) be accurately measurable, 2) show sufficient heritability, and 3) display an adequate level of variation. For such reasons, tremendous progress has been made in the swine industry toward increasing lean meat percentage over the past quarter century. However, in more recent years, meat quality traits have received more attention and have become more important in breeding programs as producers and processors try to meet consumer demands for high quality, nutritious products.

The word quality can mean many things, but most importantly, it means customer satisfaction with pork products. Many different traits have been identified as indicators of consumer acceptance of pork and include such characteristics as color, firmness, pH, tenderness, marbling, juiciness, and flavor. Though pork quality is influenced by many factors, research has shown that between 10% and 70% of the variation in meat quality can be attributed to genetics. Specifically, intramuscular fat is reported to be moderately heritable (NPPC, 1995). Accurate measurement of all meat quality traits in the live animal is not possible; however, intramuscular fat is one of the meat quality traits shown to be accurately measured in the live animal (Ragland, 1998; Newcom et al., 2001, Newcom et al., 2002). In addition, it has favorable genetic correlations with many other meat quality traits. Greater amounts of IMF have been shown to positively impact sensory panel traits such as tenderness, juiciness, and flavor, along with mechanical measures of tenderness (Hiner et al., 1965; De Vol et al., 1988; Hodgson et al., 1991; NPPC, 1995; Huff-Lonergan et al., 2002).

### Selection for Increased IMF

A selection project to increase intramuscular fat percentage was initiated at the Bilsland Memorial Swine Breeding Farm at Iowa State University in 1998. The project was started by purchasing 40 Duroc gilts from Midwest breeders. Two generations of random mating using Duroc boars available at regional boar studs were used to expand the population, and to ensure that the population represented genetics that were available in the Duroc breed at that time. A base population of 56 litters was produced in 2000.

From the litters produced in the base generation, littermate pairs of gilts were randomly chosen to produce the next generation. One gilt in each littermate pair was assigned to the select line and one littermate was assigned to the control line. Littermate gilts across both lines were mated to the same boar (via natural mating or artificial insemination) to maintain genetic ties between the lines for production of generation one. A total of 24 sires from 14 sire families were used to produce 50 control and 45 select line litters. At weaning, two boars in each litter were randomly selected to remain boars and all other boars in the litter were castrated. At an average weight of 110 kg, pigs were ultrasonically evaluated with an Aloka 500V SSD ultrasound machine for measurement of 10$^{th}$ rib off-midline backfat depth and loin muscle area. A minimum of four longitudinal images were collected 7 cm off-midline across the $10^{th}$-$13^{th}$ ribs. Texture analysis software (Amin et al., 1997) was used to estimate final IMF parameters and IMF was predicted by the method of Newcom et al. (2002). In total, 324 and 283 pigs from the control and select lines, respectively, were scanned. A total of 151 pigs (87 control and 64 select) from generation one were harvested.

Breeding values were estimated for predicted and carcass IMF by fitting a two-trait animal model and the full relationship matrix in MATVEC (Wang et al., 2003). Genetic and environmental variances were estimated using the following model: $\mathbf{y} = \mathbf{Xb} + \mathbf{Za} + \mathbf{Hd} + \boldsymbol{\beta} + \mathbf{e}$, where **y** = the vector of observations; **b** = the vector of fixed effects (scan contemporary group, harvest contemporary group, and sex), **a** = the vector of random additive genetic effect, which includes the numerator relationship matrix among animals; **d** = the vector of common litter effects, which is assumed to be uncorrelated with the random animal effects, $\boldsymbol{\beta}$ = covariate of off-test weight, and **e** = the vector of residuals. The incidence matrices relating observations to fixed, random animal, and common litter effects are **X**, **Z**, and **H**, respectively.

Selection was based on EBV for carcass IMF. In the select line, the 10 boars and 75 gilts with the highest EBV were selected. In the control line, one boar from each of the 14 sire families and 50 gilts representing all 14 sire families were randomly selected. Animals within each line were randomly mated to produce generation two, but matings were designed to control inbreeding and ensure several litters from each selected boar. The same methods of selection and mating were utilized to produce 56 select and 36 control line litters in generation two and 54 select and 38 control line litters in generation three.

In generation four, 75 select and 50 control line litters were produced. At weaning, three boars in each select litter and a minimum of six boars in each control sire group were randomly selected to remain boars and all other boars in the litter were castrated. When generation four animals reached an average of 110 kg, pigs were scanned and harvested according to the protocol previously described. A total of 810 pigs were scanned and 149 pigs were harvested from generation four. The genetic evaluation described above was performed to make selections.

## Carcass Evaluation

In each generation, all barrows within each litter meeting the minimum weight requirement (> 97 kg) were harvested 5 d after scanning. If no barrows were available, a randomly chosen gilt was harvested. Carcass measurements were obtained by Iowa State University personnel 24 h post-mortem. Standard carcass collection procedures, as outlined in Pork Composition and Quality Assessment Procedures (NPPC, 2000), were followed to obtain measurements of tenth-rib backfat (BF10) and loin muscle area (LMA). Ultimate pH was measured on the $10^{th}$ rib face of the longissimus muscle using a pH star probe (SFK Ltd, Hvidovre, Denmark). Hunter L (L24) score and Minolta Reflectance (a measure of light reflectance where lower values indicate darker and more desirable color) were measured on the $10^{th}$ rib face of the loin using a Minolta CR-310 (Minolta Camera Co., Ltd., Japan) with a 50-mm-diameter aperture, D65 illuminant, and calibrated to the white calibration plate. A section of bone-in loin containing the $10^{th}$ – $12^{th}$ ribs was excised from the carcass and transported to the Iowa State University Meat Laboratory, Ames. A 3.2 mm slice from the $10^{th}$ rib face was then removed and utilized for intramuscular fat determination (Bligh and Dyer, 1959). The 11th and 12th rib sections were cut into 2.54 cm chops and set freshly cut side up for 10 min to allow the sample to bloom. Subjective measures of color (1-6), marbling (1-10), and firmness (1-3) were evaluated on the 11th rib face according to NPPC (2000).

**Sensory Evaluation**

The 11th and 12th rib chops were vacuum packaged and taken to the Iowa State University Food Science Laboratory where they were refrigerated at 0º C for seven days. A trained sensory panel with three members evaluated cooked loin quality attributes (Huff-Lonergan et al., 2002). Chops were cooked to 71º C in an electric broiler (Amana model ARE 640, Amana, IA), with sample temperature monitored by Chromega/Alomega thermocouples attached to an Omega digital thermometer (DSS-650, Omega Engineering, Inc., Stamford, CT). Weights prior to and immediately after cooking were used to calculate percent cooking loss. Three 1.3 $cm^3$ cubes were removed from the center of the 11th rib sample and evaluated by the trained sensory panel for juiciness (1 = dry and 10 = juicy), tenderness (1 = tough and 10 = tender), chewiness (1 = not chewy and 10 = very chewy), flavor (1 = little pork flavor, bland and 10 = extremely flavorful, abundant pork flavor), and off-flavor (1 = no off-flavor and 10 = abundant non-pork flavor) using an end-anchored, 10-point scoring system (AMSA, 1995). Individual booths with red overhead lighting were provided for each panelist. Room temperature, deionized, distilled water and unsalted crackers were served between samples to cleanse the palette. Sample evaluations were averaged across panelists for analysis. The 12th rib section was evaluated for tenderness using an Instron Universal Testing Machine (Model 1122; Instron Corp., Canton, MA) fitted with a circular, five-pointed star probe (nine mm diameter with six mm between points) (Oltrogge-Hammernick and Prusa, 1987).

**Results after Four Generations of Selection**

The total number of pigs evaluated and the number of pigs harvested through generation four are presented by line in Tables 1 and 2, respectively. Least squares means for growth, carcass composition, meat quality, and eating quality traits were estimated using PROC MIXED in SAS with a model that included fixed effects of line, generation, harvest group within generation, and sex. Carcass weight was included as a covariate for the evaluation of in-plant measures of backfat and loin muscle area. Sire and dam within line were included as random effects in the model.

Least squares means for growth and carcass composition for pigs in generation four are presented in Table 3. After four generations of selection for IMF, the average EBV for select line pigs is 1.03% greater than for control line pigs. Of the pigs harvested in generation four, line LS means for tenth rib backfat and loin muscle area were 18.58 mm and 42.94 $cm^2$ in the control line, and 21.62 mm and 39.22 $cm^2$ in the select line ($P < 0.05$), respectively. Analysis of STAGES data evaluated on all 810 pigs in generation four revealed no significant difference between lines for days to 114 kg, however, compositional differences similar to those found in the pigs harvested were noted. Results through generation four indicate that selection for IMF has resulted in slightly more tenth-rib backfat and less LMA, while having no significant effect on growth performance.

Least squares means for meat and eating quality traits for generation four are presented in Table 3. Chemical analysis of a sample of pigs from each litter revealed a significant phenotypic response in IMF (3.04% in the control line vs. 3.97% in the select line) similar to the difference between lines for IMF EBV.  Line LS means for pigs harvested in generation four for 24 h Hunter L and Minolta were 45.77 and 21.99 in the control line, and 49.79 and 24.67 in the select line ($P < 0.05$), respectively.  Subjective measures of marbling were significantly different between lines (2.25 in the control line vs. 3.00 in the select line); however, subjective measures of color and firmness revealed no significant difference.  Other meat quality characteristics such as Instron tenderness, pH, and percent cooking loss, as well as sensory panel evaluations of juiciness, tenderness, chewiness, flavor, and off-flavor were not significantly different after four generations of selection for IMF.  Selection on IMF EBV has also yielded correlated responses in terms of slightly lighter and less desirable objective measures of color; however, it has had no effect on other objective measures of meat quality.  According to results through generation four, genetic and biological mechanisms controlling the deposition of IMF do not appear to be similar to those affecting sensory traits.

**Conclusions and Future Direction**

After four generations of selection for IMF using real-time ultrasound, the average EBV for select line pigs is 1.03% greater than for control line pigs.  Selection for IMF has, however, resulted in slightly more backfat and less loin muscle area, and yielded no significant response in growth performance.  A correlated response in terms of less desirable objective measures of color was found after four generations of selection; however, no other objective meat quality differences were found between the select and control lines.  No correlated responses in any measures of eating quality were detected through four generations of selection for IMF.

This study has illustrated that through four generations of selection, significant genetic response can be obtained through traditional BLUP selection.  In subsequent generations, different selection schemes will be evaluated to further enhance the genetic utility of the select line for typical commercial settings.  First of all, a selection index that includes evaluations of backfat and growth performance will be initiated to generate further genetic progress in IMF while attempting to alleviate further antagonistic correlated responses in terms of decreased lean percentage and growth performance.  This may be facilitated by the use of molecular marker information to increase accuracy of selection and enhance genetic response in IMF.  Molecular markers that describe a sufficient amount of variation in IMF have been detected.  If these genetic markers are found to be segregating within the current population and are associated with greater levels of IMF, implementation of marker assisted selection methodology may further increase the efficacy of selection in the present study.  Ultrasound technology, coupled with current selection methods and evolving molecular tools, will offer seedstock producers the opportunity to select for improved IMF in live animals and hence speed genetic progress for the improvement of this trait.

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Table 1. Distribution of records of pigs completing progeny test from a selection project for intramuscular fat in Duroc swine.

| | Control | | Select | |
|---|---|---|---|---|
| Generation | Litters | Pigs | Litters | Pigs |
| 1 | 50 | 324 | 45 | 283 |
| 2 | 36 | 235 | 56 | 348 |
| 3 | 38 | 261 | 54 | 365 |
| 4 | 50 | 346 | 75 | 464 |
| Total | 174 | 1,166 | 230 | 1,460 |

Table 2. Distribution of records of pigs harvested from a selection project for intramuscular fat in Duroc swine.

| Generation | Control | Select |
|---|---|---|
| 1 | 87 | 64 |
| 2 | 49 | 54 |
| 3 | 81 | 64 |
| 4 | 71 | 78 |
| Total | 288 | 260 |

Table 3. Least squares means for growth performance, carcass composition, meat quality, and eating quality traits from generation four of a selection project for intramuscular fat in Duroc swine.

| EBV | Select | Control | Difference | Pr > F |
|---|---|---|---|---|
| EBV for intramuscular fat, % | 1.04 | 0.01 | 1.03 | 0.0001 |
| **STAGES Data[a]** | | | | |
| Days to 114 kg | 184.80 | 183.30 | 1.50 | 0.4685 |
| Loin muscle area, $cm^2$ | 37.99 | 41.28 | -3.29 | 0.0001 |
| Tenth-rib backfat, mm | 21.34 | 19.05 | 2.29 | 0.0057 |
| **Carcass Composition[b]** | | | | |
| Loin muscle area, $cm^2$ | 39.22 | 42.94 | -3.72 | 0.0005 |
| Tenth-rib backfat, mm | 21.62 | 18.58 | 3.04 | 0.0189 |
| Last-rib backfat, mm | 23.55 | 22.30 | 1.25 | 0.2332 |
| **Meat Quality[b]** | | | | |
| Intramuscular fat percentage, % | 3.97 | 3.04 | 0.93 | 0.0030 |
| Subjective color score (1-6) | 3.24 | 3.30 | -0.06 | 0.7534 |
| Subjective firmness score (1-3) | 2.06 | 2.02 | 0.04 | 0.6101 |
| Subjective marbling score (1-10) | 3.00 | 2.25 | 0.75 | 0.0051 |
| 24 h Hunter L value (1-100)[c] | 49.79 | 45.77 | 4.02 | 0.0001 |
| 24 h Minolta reflectance, %[d] | 24.67 | 21.99 | 2.68 | 0.0032 |
| 24 h pH | 5.72 | 5.79 | -0.07 | 0.0950 |
| Percent cooking loss, % | 18.21 | 17.81 | 0.40 | 0.5119 |
| Instron tenderness, kg | 5.97 | 6.08 | -0.11 | 0.4647 |
| **Eating Quality[be]** | | | | |
| Juiciness score (1-10) | 5.72 | 5.92 | -0.20 | 0.3945 |
| Chewiness score (1-10) | 3.14 | 3.03 | 0.11 | 0.5646 |
| Tenderness score (1-10) | 5.94 | 6.23 | -0.29 | 0.2207 |
| Flavor score (1-10) | 2.92 | 2.54 | 0.51 | 0.1376 |
| Off-flavor score (1-10) | 2.44 | 2.67 | -0.23 | 0.3632 |

[a]STAGES data (http://www.ansc.purdue.edu/stages) measured on all pigs completing progeny test (n = 810).
[b]Evaluated on sample of pigs harvested from generation four (n = 149).
[c]Hunter L values are objective measures of exposed lean color (0 = black, 100 = white).
[d]Minolta reflectance (0 = 0% reflectance and 100 = 100% reflectance).
[e]Trained sensory panel evaluations of tenderness (1 = tough and 10 = tender), flavor (1 = little pork flavor, bland and 10 = extremely flavorful, abundant pork flavor), off-flavor (1 = no off-flavor and 10 = abundant non-pork flavor), juiciness (1 = dry and 10 = juicy), and chewiness (1 = not chewy and 10 = very chewy).